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UNITED STATES BUREAU OF MINES
SCOTT TURNER, DIRECTOR

INFORMATION CIRCULAR

MICA

PART I. GENERAL INFORMATION

BY

W. M. MYERS

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DEPARTMENT OF COMMERCE - BUREAU OF MINES

M I C A

PART I. GENERAL INFORMATION[1]

By W. M. Myers[2]

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1 - The Bureau of Mines will welcome reprinting of this article but requests that the following footnote acknowledgment be made: "Reprinted from U. S. Bureau of Mines Information Circular 6205.

2 - Former mineral technologist, U. S. Bureau of Mines. Original manuscript rearranged and brought up to date by Paul M. Tyler, acting chief engineer, rare metals and nonmetals division.

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GENERAL DESCRIPTION

The term mica is derived from the Latin "micare," meaning to shine or glitter. The brilliant reflection of mica is one of its most striking characteristics and has directed more than ordinary attention to this group of minerals. Mica is sometimes called isinglass, although this term should be used more correctly to apply to the semitransparent substance (gelatin) obtained from the air bladders of certain fish. Muscovite glass has also been used to designate one variety of mica, and from this term has been derived the mineralogical name "muscovite," which is applied to the most common mica.

The mica group contains a number of distinct minerals which, though more or less similar in physical properties, vary greatly in chemical composition. The most pronounced property they possess in common is a highly developed basal cleavage, which permits separation, with more or less facility, of aggregates into sheets, depending upon the variety of mica. The common varieties of mica and their formulas are given by Dana as follows:

Varieties	Theoretical formula
Muscovite	$H_2KAl_3(SiO_4)_3$
Phlogopite	$[H,K,(MgF)]_3\ Mg_3Al\ (SiO_4)_3$
Biotite	$(H,K)_2(Mg,Fe)_2\ (Al,Fe)_2\ (SiO_4)_3$
Lepidolite	$K,Li\ [(Al(OH,F)_2]\ Al\ (SiO_3)_3$
Roscoelite	$H_8K(Mg,Fe)\ (Al.V)_4\ (SiO_3)_{12}$
Paragonite	$H_2NaAl_3(SiO_4)_3$
Zinnwaldite	$(K,Li)_3\ FeAl_3\ Si_5O_{16}(OH,F)_2$?
Lepidomeland	Similar to biotite, rich in ferric iron.

These formulas have not been established definitely and are of little value, except to indicate that micas are complex silicates of variable composition. The micas are commonly classified according to their dominant component. Muscovite is called potash mica; phlogopite, magnesium mica; biotite, iron mica; lepidolite, lithium mica; roscoelite, vanadium mica; and paragonite, sodium mica.

Muscovite and phlogopite are the micas of commerce. Both varieties occur in comparative abundance and are found in crystals of sufficient size to yield fairly large sheets. They also possess the transparency and dielectric strength which are the most desirable properties of mica. The other varieties of mica do not possess the qualifications necessary for industrial use in the same fields in which muscovite and phlogopite are employed although some of them have other characteristics that have brought them into a limited commercial use.

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The following description of the properties, production, and utilization of mica applies only to muscovite and phlogopite. The properties and use of the other micas are discussed briefly at the end of this report.

MUSCOVITE

Muscovite, or white mica, is the most important mica and is the only variety mined extensively in the United States. Muscovite crystallizes in the monoclinic system and occasionally is found in very large crystals. The characteristic basal cleavage is highly developed. Crystals with a rhombic or hexagonal outline are of common occurrence and are apt to confuse the true crystallization. The angles between the prismatic faces vary somewhat from the 120° angles of a true hexagon; and this, together with certain other morphological and optical characteristics which muscovite displays, places it in the monoclinic system. If a sheet of this mica is struck with a sharp instrument a typical percussion figure appears. This figure is formed by three intersecting fractures which form a 6-rayed star with angles of approximately 60° between each ray. Muscovite has a hardness between 2 and 2.5 on the Mohs scale. The specific gravity ranges from 2.7 to 3.0 and the index of refraction from 1.56 to 1.60. Thin plates are transparent, but larger mica masses are opaque. The color varies greatly. Thin sheets are generally nearly colorless, and color becomes evident only in the thicker plates. Varying shades of green, gray, and reddish-brown are most common. A zonal distribution of color following the crystal structure is sometimes noted. The luster is commonly vitreous. The very smooth surface of the natural cleavage reflects light very efficiently and produces a brilliant reflection. Thin sheets are both flexible and elastic.

Muscovite has a marked tendency to intercrystallize with other minerals. This is unfortunate, as the presence of these other minerals has ruined a great deal of mica which otherwise would be quite usable. The most common included impurity is magnetite (magnetic oxide of iron), the presence of which greatly lowers the electrical resistance of the mica. This impurity is dark brown or black but often has been altered to other oxides of iron that are light brown or yellow. Garnet, rutile, and tourmaline, as well as other micas, particularly biotite, are often found intergrown with muscovite.

The physical properties of mica from different localities vary greatly. Differences in the perfection of cleavage affect the ease with which the mica may be prepared for use. Increased hardness is generally a detriment, as the softer micas are in demand. Flexible mica is necessary for some uses. Freedom from color and perfect transparency are essential for others. Practically all the industrial uses of mica are dependent upon its physical properties and not upon its chemical composition. A study of these properties is therefore desirable especially when a new mine is under development as the markets in which the production may be sold and the price which can be obtained may be greatly restricted due to the imperfect development of some of these qualities.

Chemical Composition

The following analyses indicate the composition of muscovite from different localities. The isomorphous substitution of equivalent radicals causes endless variation in composition.

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Composition of muscovite from various localities

	Theoretical	Bengal[1]	Connecticut[1]	North Carolina[2]	California[2]
SiO_2	45.2	45.57	45.05	45.40	45.63
TiO_2	.....	.....	.....	1.10	Trace
Al_2O_3	38.5	36.72	30.57	33.66	37.42
Fe_2O_3	.....	.95	1.14	2.36	Trace
FeO	.....	1.28	1.73	.....	.06 MnO
MgO	.....	.38	.97	1.86	.....
CaO	.....	.21	.....	.....	.....
Na_2	.....	.62	2.13	1.41	1.43
K_2O	11.8	8.81	10.23	8.33	9.95
LiO_2	.....	.19	.....	Trace	.20
H_2O	4.5	5.05	6.19	5.46	4.43
F	.....	.15	1.25	.69	.77
	100.0	99.93	99.27	100.27	99.89

1/ From Iddings, Joseph P., Rock Minerals: 1906, p. 420.
2/ From Clark, F. W., Analyses of Rocks and Minerals: U. S. Geol. Survey, Bull. 591, 1915, p. 330.

Occurrence

Muscovite is widely distributed in a variety of rocks. It is present in enormous quantities as one of the essential rock-forming minerals of granites, schists, and gneisses; but in this form it has very little commercial significance, as the scales are small and ordinarily can not be recovered economically. Recently, however, some mica schists containing an unusually high percentage of mica have been used to a limited extent as a source of mica for grinding. The weathering of these rocks has liberated large quantities of mica in unconsolidated mixtures of mica scales, quartz, and kaolin or partly kaolinized feldspar. If the market for ground mica continues to expand it is probable that more attention will be paid in future to material of this type as a source of mica suitable for grinding. A considerable quantity of finely divided mica is already recovered in the Southern States as a by-product in washing china clay.

Muscovite of commercial size--that is, sheets at least 1½ by 2 inches --is found invariably in deposits of pegmatitic origin. These pegmatites are similar to granites in mineralogical composition but are characterized by very coarse crystallization. The essential minerals are feldspar and quartz.

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Muscovite is a common accessory. Tourmaline, garnet, apatite, beryl, topaz, spodumene, amblygonite, cassiterite, or tantalite is often present also, but ordinarily only in relatively small quantities. The exceedingly coarse crystallization encountered in many pegmatites is of great importance to the mica industry in that it provides large masses or books of mica from which sheets of considerable area can be obtained. Single crystals of mica weighing over 2 tons have been discovered. Similarly, these pegmatites supply very large crystals of spodumene, beryl, quartz, and feldspar; and these accompanying minerals may be of interest, not only from a mineralogical standpoint but commercially.

Pegmatites vary in width from a few inches to several hundred feet. They are irregular in form, appearing as stocks, chimneys, lenses, sheets, or masses surrounded by rocks of a granitic character. Branching and sudden contraction in width are common. The largest crystals of mica are generally found where coarse crystallization prevails. The crystals of mica may be scattered throughout the pegmatite irregularly or may display a tendency to concentrate near the contacts with the surrounding rock. Among the risks of mica mining are the possibilities that the size of the vein, the mica content, or the size and quality of the individual mica crystals or books may diminish to unprofitable proportions with little or no warning.

Feldspar is the most common mineral found in pegmatites and often constitutes 50 to 90 per cent of the rock mass. Feldspar alters readily, forming other minerals, particularly kaolin. This kaolinization is accelerated by moisture and warm temperatures and frequently proceeds to considerable depths, as in the numerous "flucans" dikes in the Southern States. This results in a chemical and physical disintegration of the rock, so that it may be easily excavated. Mica is often unattacked by the agencies that cause kaolinization and may be found unchanged, although the surrounding feldspars have been entirely altered.

Although muscovite large enough for use as sheet mica is found only in pegmatites the occurrence of pegmatite formations does not imply the presence of marketable mica. This is illustrated in several States that contain large areas where such pegmatites are common but no appreciable amount of mica for commercial use is produced.

One of the most essential requirements for sheet mica is that it be flat and free from folding and distortion. The degree of metamorphism to which the region has been subjected during or subsequent to crystallization of the mica is therefore an important factor. Where the agencies producing metamorphism, particularly great pressure and accompanying movement, have been in evidence, the mica may have been so distorted as to be wavy, ruled, and with an imperfect cleavage so that even sheets can not be produced. Mica of this nature is worthless for the manufacture of sheet material and can only be used for the manufacture of ground mica. The best mica is found in regions of geologic stability. The largest and most important mica-producing areas of the world are in such regions.

PHLOGOPITE

Phlogopite, more commonly known as amber mica, has not been found in

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the United States in commercial quantities, although it has been noted in small deposits in some areas. Deposits in New York and New Jersey were worked for a short time but did not prove to be large enough to justify continued operation.

Phlogopite crystallizes in the monoclinic system but like muscovite often appears in crystals having a hexagonal outline. It possesses a perfect basal cleavage that permits separation of blocks into thin sheets with great facility. Thin sheets display a typical amber color and appear to be as flexible and elastic as muscovite. The specific gravity ranges from 2.8 to 3.0 and the index of refraction from 1.56 to 1.61.

The hardness is usually reported as being 2.8 to 3.0 or somewhat harder than muscovite. Nevertheless, since phlogopite is used commercially at points where a soft mica is required one would suppose that it actually is softer than muscovite. The hardness of mica, however, is ordinarily determined by noting the rate of abrasion upon the edge of a sheet, and it has been stated[3] that the softness of phlogopite is due more to its brittleness and friability than to a lack in true hardness. Possible differences in the hardness on the edge as compared with that on the face of a sheet may also contribute to this apparent anomaly.

Chemical Composition

Chemically phlogopite is characterized by a high magnesia content, as shown in the following analysis[4]

	Sample from Edwards, N. Y.	Sample from Burgess, Canada
SiO_2	45.05	39.66
TiO_2	.....	.56
Al_2O_3	11.25	17.00
Fe_2O_3	.....	.27
FeO	.14	.20
BaO	.....	.62
MgO	29.38	26.49
LiO_2	.07	.....
Na_2O	.45	.60
K_2O	8.52	9.97
H_2O	5.37	2.99
F	.....	2.24
	100.23	100.30

The percentage of iron in some phlogopites is often greatly in excess of that indicated above.

3/ Schroeder, Richard, Mica and Mica Products: Published by Julius H. Springer, Berlin.

4/ Clark, F. W., Analyses of Rocks and Minerals: U. S. Geol. Survey Bull. 591, 1915, p. 533.

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Occurrence

According to a letter from W. T.Schaller, phlogopite may be very abundant in regions of contact metamorphism, but sheets of commercial size are found in only a few places. So far as known commercial deposits are all of the dike type, the phlogopite forming an essential part of the injected dike rock. This form of occurrence is similar to that of muscovite, except that the other constituents of the dike are different, being chiefly pyroxene (diopside), apatite, and calcite, usually with smaller quantities of hornblende, pyrite, and other minerals. In some of these dikes, phlogopite forms over 90 per cent of the rock mass, occurring in sheets and rude crystals a foot or more in thickness.

Phlogopite commonly occurs as disseminated crystals and sheets scattered through large areas of metamorphosed rock, usually limestone that may originally have been dolomitic in character. In such disseminated occurrences only local concentrations of large sheets could develop into commercial possibilities, and no deposits of this type have been worked.

USES OF MICA

Mica possesses a peculiar combination of useful physical properties. Its perfect cleavage, high dielectric strength, mechanical strength, flexibility, transparency, mechanical stability, heat resistance, nonabsorption, and luster have made the mineral serviceable in many industries. For many purposes it is virtually indispensable, as no satisfactory substitutes have been found.

By far the most important function of mica is as an insulator in the electrical industry, particularly where noninflammability or extraordinary resistivity is essential. Quantities of sheet mica are used in various household electrical appliances. Mica washers of different sizes formed into hollow rods or tubes and bonded with shellac are used as insulating sleeves and bushings of electrical machinery and X-ray apparatus. Mica tubes are also made of mica splittings cemented by shellac or glyptol and rolled to the proper thickness. Ground mica cemented by means of lead borate is also employed for insulation.

Natural sheet mica is used principally in flat insulation, the larger sizes being employed in a wide range of shapes. Various heater shapes, upon which the resistance elements of electrical appliances such as flat irons are wound, are made from "pattern mica". Small articles, such as commutator segments, disks, washers, and sundry small shapes used in the electrical industry, are made from "punch mica". It is estimated that nearly 90 per cent of the world's production of sheet mica, including punch mica, is utilized in electrical insulation.5/

Mica windows in house-heating stoves constitute a use that is well known, though of declining importance. Substantial quantities of sheet mica are used, however, as glazing material in lamp chimneys, lanterns, projection lantern slides, canopies and shields, eye protectors, peepholes for furnaces and ovens, and similar transparent articles exposed to heat. Phonograph diaphragms were formerly made of mica but have now been almost wholly displaced by a new type of metal diaphragm.

5/ Spence, Hugh S., Mineral Industry: Vol. 37, 1928, p. 414.

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Mica splittings, which are thin films of mica, are used with suitable cement in the manufacture of built-up mica board and other forms of electrical insulation. Tapes, cloth, and paper faced with mica splittings are also used for insulating.

Both sheet and built-up mica are used to some extent for decorative purposes, notably in lamp shades, and coarsely ground mica is extensively employed as "Christmas tree snow" during the holidays and for decorative purposes on post cards, wall paper, stucco, and plasters.

Ground mica is used in great quantities in dusting automobile tires, rolled roofing, and asphalt shingles and as a filler in rubber goods, particularly soft rubber articles and plastic wall finishes. It also has a variety of miscellaneous uses, for example, in heat insulating, annealing steel, and lubricating, in paints, and in ceramics.

For electrical insulating purposes both muscovite and phlogopite (amber mica) are used. The latter, however, is often preferred where high temperatures are involved or for commutator insulation since it wears down easily with the copper and does not need to be undercut. For some miscellaneous purposes clear sheet lepidolite may be used in place of muscovite as it has the advantage of greater hardness. Vermiculite, calcined and ground, is preferred to other varieties of mica for heat-insulating and sound-deadening purposes and also competes with other kinds of ground mica for decorative finishes, and in paints and lubricants. Biotite is also employed as ground mica.

HISTORY OF MICA MINING IN THE UNITED STATES

There is evidence that the production of mica was the first mining industry developed in North America. In any event, mica mining was carried on by the aboriginal occupants of this country at an unknown date. Many ancient workings have been found in western North Carolina, and thousands of tons of debris still lying on the dumps indicate that the mining of mica was an extensive and important occupation. Ancient mines which have been found consisted of small irregular workings that evidently followed the richest concentrations of mica. Mining was carried on in the oxidized portions of the pegmatites in which the feldspar had been partly kaolinized, which facilitated mining. Operations ceased when hard rock was encountered, as the tools employed could not break it. Considerable mystery surrounds these old workings, but they are believed to have been made by the ancient mound builders, inasmuch as mica ornaments have been uncovered in excavated mounds in the Ohio Valley. Just what value was attached to mica by these aboriginal miners is not known. A small amount of mica has been found in excavations but not enough to account for the large quantities that must have been extracted. It has been suggested that this material may have been utilized as a medicine, as is done in India at present. These ancient miners evidently possessed accurate information concerning the location of good deposits of mica, and it has been commonly observed that when these have been reopened they have furnished large quantities of mica of excellent quality.

The Ruggles mine in New Hampshire was first operated in 1803 and was probably the first mica mine to be exploited on a commercial scale. The

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first production of mica from New Hampshire was employed for stove windows and also to a limited extent in glazing on gunboats where concussion from gunfire was sufficient to shatter glass. Early mining in New Hampshire was carried on irregularly, and production had little importance until after the Civil War. Mica mining on a modern scale was begun in North Carolina about 1868, and production from this State for many years was the controlling factor in the American market.

The first demands for mica were for large sheets suitable for glazing purposes and it was not until the insulating properties of mica in electrical equipment were recognized that an active demand for high-class material developed. This started approximately in 1890, and since that date the increasing demands of the electrical industries have dominated the mica market. The use of mica as a glazing material has gradually declined; and in the last few years, during which time the use of heating stoves has decreased, this market has greatly diminished.

Mica deposits have been known in India from an early date and since 1885 the importations of India mica to this country have increased steadily. In 1894 the process of manufacturing built-up mica board from mica splittings was discovered. The large-size sheets which may be constructed in this manner and the ease with which mica may be fabricated have steadily increased the market for this material. Until very recently splittings have been manufactured only by hand; and India, with a large supply of cheap labor and easily splitting mica produces approximately 70 per cent of the world's supply of mica and is able to maintain a dominating position in this industry. Splittings have been manufactured at times in this country and still are produced from amber mica in Canada.

PROSPECTING

Prospecting for mica consists essentially of first locating a pegmatite which may contain mica and then determining by exploration the quality and quantity of mica available. Where pegmatites do not outcrop their presence can not be detected readily. In the United States, especially in New England, glaciation has eroded the surface so that little overburden is left, and many pegmatite outcrops are exposed. Some of these exposure pegmatites have been developed into successful producers of mica and feldspar. In the Southern States the presence of pegmatites is often indicated by the disintegration products formed by kaolinization of the feldspars. Unaltered mica is frequently found in the kaolin; and its presence on the surface, where it is readily detected by its glittering reflection, may be a valuable guide to its occurrence in the underlying rock. At times the course of a pegmatite may be traced for a considerable distance by the presence of the mica in the overlying soil.

The occurrence and structures of pegmatites, together with the uncertainty of their mica content, are such that systematic prospecting is seldom justified. Rarely does it pay to locate deposits by tunnels at regular intervals or by diamond drilling. Ditching to a shallow depth across the surface may sometimes be helpful, and it often pays to sink short holes with soil augers or similar equipment to determine the nature of the soil below the surface. After a promising-looking pegmatite has been discovered the ordinary

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procedure is to sink a shaft or drive a drift into the rock where the most mica is in evidence. If the mica proves to be too poor in quality or if it is not present in quantity sufficient to warrant continued operation the prospect is abandoned before any great financial investment has been made. If the prospecting appears promising, mining is continued in the most economical manner until enough mica is recovered for sale to afford some idea of the returns in comparison with the costs of operation.

MINING METHODS6/

The irregular structure of pegmatites has had a very notable effect on the development of mica mines, for it has tended to discourage large systematic operations. As mining is continued the pegmatite formation may suddenly decrease in size, or the mica may cease to be present in paying quantities. In view of these uncertainties operators are reluctant to undertake any extensive program of preliminary development.

The industry as a whole is characterized by a large number of small operations of shallow depth, many of which are worked intermittently according to the price of mica or the leisure of the operator, and in general it may be stated that these workings are carried on very irregularly with a minimum of mechanical equipment or financial investment. Mica mines in this country may be classified briefly in three groups; (1) Those that are small and irregularly operated, (2) those that have been successful in a small way and have been increased in size and equipped with some mechanical aids, and (3) large well-equipped mines that are operated according to a systematic mining method.

The first group represents mining in its most elementary form, often called "gophering" or "ground hogging", and produces small irregular excavations with a single aim of recovering as much mica as possible at the least expense. Only the simplest equipment is used--mostly picks and shovels in the decomposed, upper zone. When hard rock is encountered it is drilled by hand and shot with black powder or 40 per cent dynamite. Mining is carried on in a most irregular manner, and small tunnels are driven from one mica crystal, commonly called a "book", to the next so that the most mica may be recovered with a minimum of rock handled. Where conditions are favorable these crude methods sometimes result in the recovery of considerable good sheet mica, but usually they fail to recover a large percentage, and when abandoned they leave the deposit in an unfavorable condition for reopening. From the national viewpoint, therefore, such operations are uneconomic, although they may be justified to the extent that they permit the extraction of some mica at a profit and also serve to prospect unknown ground, with the result that the property may finally be developed into a real mine. Where the pegmatite outcrops on a hillside a tunnel driven in so that it will afford a natural drainage is often a great help. Some open-pit workings have been abandoned as soon as the excavation reached water level as no pumping equipment was available.

Where these small operations disclose good ore bodies more systematic operations and the purchase of better mechanical equipment may be justified. Many of these mines, in the second classification, are provided with

6/ For specific examples of mining methods at individual properties the reader is referred to the forthcoming information circular by F. W. Horton on Domestic and Foreign Deposits.

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air compressors so that mechanical drilling is possible and with pumps to remove water. They may be timbered sufficiently to hold the walls. A typical mine of this class consists of an irregular excavation which has been driven through a pegmatite at an angle of 35 to 40°. Tracks are laid on the incline, and hoisting is done with a steam hoist so that cars of mica or waste may be brought to the surface and taken to sorting or storage sheds or trammed to the dump. Systematic stoping is generally impossible because of the irregularities of the deposit, and a simple breast stope is driven where the occurrence of mica is most pronounced. It is sometimes noted that mica will tend to concentrate on one of the walls, and this may be a valuable aid in mining. It is also occasionally noted that the large valuable crystals of mica are found associated with large masses of quartz or feldspar, and mining is restricted to these points where the coarse crystallization seems to be most favorable. Stulls are placed across the stope as needed to prevent slabbing from the walls, and a small amount of timbering done where necessary to hold the roof.

In drilling the rock care must be taken not to penetrate the mica crystals in order to avoid damaging valuable material. An experienced miner can readily detect the presence of mica under the drill, as it drills with a peculiar resilience and is not readily penetrated. Forty per cent dynamite is the explosive most commonly used, and after the round has been fired and the air has been cleared the mica is separated from the other minerals and thrown into a car and hoisted to the surface. The recovery of feldspar as a by-product is sometimes possible, and in this instance the feldspar is also sorted out and trammed to its separate dump. This process of working down an incline on the outcrop of a pegmatite with an inclined shaft and irregular stopes is probably the most common method of underground mining. Some flat-lying formations have been worked by room-and-pillar method leaving enough pillars to provide a support. The possibility that the mine may suddenly cease to be profitable necessitates a minimum financial investment and the use of equipment that may be moved readily to another locality if necessary.

The third class of mines, comprising the few systematic, well-organized operations, is found only where pegmatites have been discovered that are large enough and contain enough mica to assure some permanence of operation. Such mines have been developed in New Hampshire, North Carolina, Alabama, and South Dakota. A remarkably large number of workable mica-bearing pegmatites dip at angles ranging from 35 to 60° from the horizontal. Some of the best examples of well-planned mines are in deposits that have such a structure. Ordinary practice is to sink a vertical shaft in the country rock on the hanging-wall side or an inclined shaft on the foot-wall side. In either instance drifts are driven to the pegmatite, and the mica-bearing rock is removed by breast or overhead stoping.

There is undoubtedly considerable justification for the crudities that characterize mica mining. The irregularity of the pegmatite deposits and the uncertainty of the presence of mica increase the hazard of successful operation. When one pocket of mica is exhausted there is no means of determining another, except by continued mining in waste ground. Diamond drilling might be of some assistance but is rather expensive, and results might be misleading. The value of a deposit depends not only upon the amount of mica

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present but also upon the quality, which can be determined only by examination and use. The miner, therefore, is constantly confronted with uncertainty regarding both supply and quality.

The feldspar production of the country is obtained from similar pegmatites, and in many of the feldspar-mining operations mica is the valuable by-product. A number of the feldspar mines or quarries have been developed on a large scale, owing to the necessity of producing a large tonnage to justify operation. These feldspar deposits are generally worked as opencut quarries, although there seems to be an increasing tendency toward underground operation. They are generally equipped with air compressors, mechanical drills, and mechanical haulage for removal of the ore. The rock is stripped, if necessary, to remove overburden, drilled with jack hammers, and shot with the proper explosive, generally 40 per cent dynamite. The broken ore is cobbed by hand and the clean spar thrown into quarry cars for removal to the storage bins. The mica found is generally thrown to one side and later sorted into clear, flat material for trimming into sheets and scrap, which is set aside for grinding. The production of by-product mica in feldspar mining often provides an additional source of revenue which may pay a large part of the cost of operation.

IMPERFECTIONS

Flat, unstained mica is the most valuable, and as much of the mine-run material contains imperfections which must be removed it is necessary to split and grade the mine-run mica with great care so that a maximum of sheet material may be recovered.

Disturbed crystallization is one of the most important sources of imperfections in mica. It causes rumpling and distortion of the mica crystals, so that flat, clear material can not be recovered. Many terms are used to describe mica of this class. "Tangle-sheet" or "tangle-foot" mica splits imperfectly and with tearing of the sheets. "Ruled" mica contains planes of separation other than the regular cleavage planes. Many terms are used to describe this condition, such as "ribbon," "wedge," "spearhead," "A", "hair-lined", "reeved", "fishbone", "herringbone", and "horsetail". These parting planes are probably caused by pressure on the mica crystals during or after crystallization, so that gliding planes have been produced. A great deal of mica is ruined and has little commercial value due to this cause. Such material is suitable only for grinding and can be classified only as scrap mica.

"Wedge" mica is a term applied to blocks that are thicker on one side than on the other. It is impossible to split films of uniform thickness from such blocks, and the value of the material is decreased. Intergrowths of crystals of other materials are common and mixed crystals of muscovite mica with biotite mica, garnet or tourmaline are occasionally encountered.

Specks and Stains

Spotted or specked mica contains thin scales or streaks of dark minerals, principally the iron oxides that are not crystallized with the mica so that they lie between the laminae but do not penetrate into the sheets any considerable distance. The inclusions in some crystals are arranged in

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patterns corresponding to certain crystallographic directions of the mica. Many interesting and peculiar patterns are produced thus. At times the inclusions will be so abundant that the mica is rendered opaque. Black stains usually consist of magnetite whose presence can be identified readily by removing the stain and testing it with an ordinary magnet. This magnetite sometimes alters to other oxides of iron, producing red or yellow stains of hematite or limonite. The presence of small amounts of magnetite between the laminae does not greatly affect the insulating power of the mica for low-voltage uses, and this material finds considerable use in the electrical industries in spite of its stain and unattractive appearance.

Clay Stains

Mica which contains clay between the laminae is called clay-stained. This condition is most commonly met with at or near the surface of the deposit in the zone of weathering and tends to disappear with depth. The mica crystals at the surface are often opened up by weathering agencies and are easily contaminated by the surrounding soil.

Color

The color of mica depends upon the thickness of the block that is observed. The thicker the blocks the more pronounced and darker the color. Very thin sheets are generally colorless, even if obtained from a block which has a pronounced color characteristic. The most common colors are rum, ruby, amber, or various shades of green. Coloring has very little industrial importance, although occasionally it is used to identify the source from which the mica came. In general the ruby mica is softer and the green mica tends to be of greater hardness.

Brittleness

For some purposes mica is curled into small tubes or bent to fairly sharp angles, and to meet these conditions it must bend without breaking. A common field test is to take a thin film and wrap it around a pencil.

Air Bells

Much mica is ruined by the presence of air bells, which often are present in such quantity as to make the mica practically worthless. The highest quality of mica should be free from all air inclusions and should be perfectly sound when examined by transmitted light. Due to strains on the mica, possibly when it was in the ground and also afterward when in the course of manufacture it has been subjected to rough handling, it often happens that air bells appear between the laminae. If these bells are large they have little importance and can not be considered a serious detriment because they can be removed by splitting the mica block along the laminae that contain the air. In some instances it happens that the mica blocks are so filled with air bells that are universally distributed between practically all of the laminae that their removal by careful splitting is entirely impossible. This material has comparatively little value, as the air inclusions can not be removed, and their presence renders the mica so unsound that it is unsuitable for most commercial work.

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TRIMMING AND CUTTING

The sorting, cleaning, grading, trimming, and cutting of mica are essentially hand processes, and little progress has been made in developing machines capable of doing this work. The sorting and trimming of mica require constant use of judgment on the part of the operator, so that a maximum of the most valuable material may be recovered. It is therefore necessary to use hand labor, and for this reason producing localities with an abundant supply of cheap labor, have a very decided advantage over regions where labor costs are higher.

Rough Trimming or "Cobbing"

The masses of mica as taken from the mine may be roughly hexagonal in shape but are more commonly in the form of irregular masses. These masses are termed "mine-run", "run-of-mine", "book mica", or "block mica." The term "block mica" is unfortunate, however, because it is also applied to imported sheet mica. The mica is first "cobbed" to remove all adhering rock, and ruled, wrinkled or otherwise defective blocks are discarded as scrap. The blocks are rapped with hammers to separate adhering dirt. Rough mica is commonly passed over a $\frac{1}{2}$-inch screen to remove dirt and small fragments. The small pieces are later utilized as scrap.

Trimming sheds are provided at some mines, but most of the small miners sell their rough-cobbed mica to firms that sort, trim, and manufacture the product into forms desired by electrical companies and other consumers.

Rifting

Cobbed mica of good quality is split into sheets 1/8 inch thick or less. Workmen who perform this operation are known locally as "rifters." Where imperfections are present at intervals between the laminae skill and judgment are required so to split the blocks that the imperfections may be removed. The increased percentage of high-grade mica that may be obtained by proper splitting certainly justifies the employment of skilled rifters.

In handling amber mica the masses, which may be several inches thick, are first split into plates about $\frac{1}{4}$ inch thick. The edges of these plates are then hammered to loosen the laminae, so that the splitting knife may be easily inserted. A double-edge 3-inch blade with a V point is used. The sheets are split to about 1/16 inch, and all edge imperfections are cut away.

Thumb-Trimming and Knife-Trimming

After rifting, the sheets may be "thumb-trimmed" by breaking off with the fingers all inferior material around edges, or they may be "knife-trimmed." The removal of the zone of etched, crushed, or tangled mica from the outer edges greatly facilitates further splitting. "Sickle-trimmed" or "Indian-trimmed" imported mica is closely "knife-trimmed", practically all flaws and cracks being removed. In this respect it differs from domestic "knife-trimmed," much of which is marred by cracks and flaws. The "sickle-

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trimmed" sheets are irregular rounded rectangles cut with beveled edges. "Madras-trimmed" mica is that obtained from Madras, India. It is cut into approximately square patterns and is known as "shear-trimmed," for it is cut with shears, and the edges are not beveled but are cut normal to the cleavage plane. Trimmed mica is known as "uncut" or "unmanufactured." It is graded according to size and quality. It may be sold to the consumer uncut, or it may be cut into any desired final size or shape.

MANUFACTURE OF SHEET MICA

Many standard shapes and sizes of sheet mica may be kept in stock, but no manufacturer who is unfamiliar with the requirements of the trade and the relative demand for various sizes and shapes should attempt to cut mica to final form. Some companies have been almost if not quite bankrupted by stocking up with unpopular sizes that would not sell. Unless thoroughly familiar with the consumer's requirements a manufacturer either should sell his mica uncut or should cut only on contract.

Uncut mica is split into thin films and cut into various rectangles, circles, or more complex forms. The smaller masses are either made into splittings, as described later, or manufactured into disks, washers, and various small forms. Washers and related forms are made with power machines fitted with compound dies, cutting outside and center hole at one operation. Washers vary in size from 5/8 inch to 2 inches in diameter, and the center holes from 1/4 inch to 1 inch. Washers may be built up with shellac to any thickness desired. Aside from the die machines practically all trimming is done by hand, though an electrically operated rotary trimmer has been used in Canada.

Most of the trimming and cutting, including the operation of die machines, is done by girls. The tools employed in mica trimming and splitting are very simple and consist of hammers, splitting knives, scissors, and heavy hinged knives like paper cutters. A thin-bladed hardwood splitting knife is sometimes used, for wood is less liable than metal to scratch the soft surface of the mica. A rasp may be fastened to the bench in a convenient position to rub the edge of the block of mica so as to open up the sheets for splitting. Trimmers are provided with a set of wood, metal, or composition blocks or templets of the various standard shapes and sizes. Cutters become skilled in judging instantly the maximum standard size that any given sheet will provide. The proper templet is placed on the sheet, and the latter is trimmed to size with the scissors. The hinged blade is used chiefly to trim the larger sheets of stove mica.

The finished sheets are carefully sorted according to size and quality and placed in packages containing a specified number or weight. They may be rectangular, circular, or curved, or may be of more complex design. It is imperative that the sheets in a package be uniform in quality and color. Canadian records show that each trimmer of amber mica produces 40 to 45 pounds of medium-size sheet mica per day.

Considerable improvement is possible in the trimming and grading of mica, and such improvements would assist greatly in popularizing domestic

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mica. Mica users prefer India mica in many instances, not because of superior quality, but because it is so carefully graded and trimmed that little waste results from manufacturing processes. Much of the domestic mica is not so closely trimmed or carefully graded; therefore a much higher percentage of loss results, and the consumer is prejudiced against the American product.

There is a very high percentage of waste in the trimming and cutting processes. Usually 90 per cent or more of the original block is cut away and can be used only as scrap for grinding. The small proportion of finished sheet mica obtainable renders many mica enterprises unprofitable. A careful inquiry by the United States Geological Survey indicated that from 1916 to 1918 block mica as obtained from a number of important mines yielded only 9 per cent of uncut sheet and 23 per cent of uncut punch. The final yield of cut mica was 3 per cent of sheet and 8 per cent of washers, while the remaining 89 per cent was scrap.

MICA SPLITTINGS

Large quantities of mica are consumed in the form of splittings for the manufacture of built-up mica board. These splittings consist of films 0.0007 to 0.001 inch thick and are made from pieces too small to use for sheet material, or, where a better quality is desired, from the small sizes of sheet stock. Splittings must be at least 1 square inch in area, must have no thick edge, and must be free from all inclusions of other minerals. Splittings produced in Canada from amber mica are known as "thin split mica," and in the United States the terms "skimmings" and "films" are sometimes used.

Practically all muscovite splittings come from India, where the splitting is done mostly by children. The children not only work cheaper, but they have a delicacy of touch that is an aid in the production of such thin films. Two classes of splittings are produced. Loose splittings made from irregular pieces of mica are small and characteristically irregular in outline. Pan-packed splittings are made from small sheet goods, generally sizes 4, 5, and 6. This material, having been prepared from trimmed sheets, has even outlines and greater area and is packed in pans to produce a laminated coherent mass. The price of pan-packed splittings is necessarily much greater than that of loose splittings.

Phlogopite splittings are manufactured in Canada and Madagascar. Some of the Canadian mica has also been split mechanically in the United States.

Mica-Splitting Devices

In the United States the labor cost of splitting by the usual hand methods has proved prohibitive. A great deal of money has been spent in fruitless attempts to manufacture splittings mechanically. A promising device consists of a frame in which the block of mica can be gripped and then pierced on the edge by a point, a micrometer attachment being provided so that the thickness may be regulated accurately. It is necessary to complete the splitting by hand, however, and the machine has never proved a commercial success. A number of patents have been issued for other splitting devices, but their use has not become established in the mica industry.

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Quite recently (1928) there was put into operation at Valparaiso, Ind., a splitting machine utilizing an entirely new principle. Small books of mica are fed between two belts which run over a number of pulleys. The bending action gradually separates the films of mica in the book, and the splittings are finally delivered to a trommel which removes the dust and small flakes. The splittings then drop in front of a suction drum from which they are delivered and laid flat, ready for the application of a liquid binder such as shellac or glyptal, for the manufacture of mica board.

SCRAP MICA

Scrap mica consists of material that, due to imperfections, can not be manufactured into sheet goods. Scrap is classified according to origin as mine scrap or shop scrap. The mine scrap consists of the folded, imperfect, or discolored mica which has been discarded at the mine during the sorting of mine-run ore. Mine scrap is contaminated by adhering impurities. Shop scrap is composed of the trimmings produced as a by-product during the manufacture of sheets or films. As this material is obtained from mica that has been subject to selection it is cleaner and has a better color than mine scrap. The flake mica recovered in clay-washing operations may also be classified as scrap, as it is utilized in the same manner. Scrap mica must be prepared for the market by grinding to the sizes required for industrial use.

The preparation of ground mica originated in the United States, and production has been limited almost entirely to this country. Operations were begun about 1890, and production has increased steadily in volume since that date. A few mines have been operated for scrap alone. In these properties the mica was found in large quantities but was either too small or too imperfect for use as sheet. With an increased demand for scrap mica more attention has been paid to its recovery from other sources. Considerable mica associated with feldspar and kaolin is recovered as a by-product and sold for grinding.

GROUND MICA

Mica is ground both by wet and dry methods. In general, the tendency is to use dry grinding to produce coarse material and wet grinding for the finer sizes. The production of ground mica in the United States has grown so rapidly in recent years that it has commenced to assume the proportions of a separate and fairly substantial industry. For this reason it is being made the subject of a forthcoming information circular of the Bureau of Mines prepared by F. W. Horton, and will be treated quite briefly in the present paper.

The grinding of mica presents one of the most difficult problems in the milling of nonmetallic ores. The peculiar combination of properties that mica displays, particularly its cohesion, toughness, flexibility, and smooth surfaces, makes it difficult for any type of mechanical equipment to grasp the mica so that it can be torn or reduced in size. Mica presents the unusual phenomenon of a soft mineral with a highly developed cleavage that makes it difficult to reduce to a ground condition. The results attained with mechanical beaters are somewhat similar to that obtained by hitting a feather with a sledge hammer, and the work accomplished is in no wise proportionate to the energy expended. A certain amount of secrecy surrounds mica-grinding

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mills, although the methods employed present nothing new other than the adaptation of well-known grinding methods to the problem in hand.

Wet Grinding

The first type of equipment employed in wet grinding consisted of simple tubs provided with impellers for stirring the charge. These tubs are upright cylinders constructed of wooden blocks with the end grain exposed to resist abrasion. The impeller is a wooden disk that fits loosely within the cylinder. The cylinder is filled with clean scrap mica, and enough water is added to permit free motion of the charge. The impeller is then pressed down on the mass and started revolving. The friction of the disk churns the entire mass so that the mica is constantly being split and abraded by the mutual impact and friction of one piece on another. The friction is so great that the water actually boils. Grinding is slow, eight hours being commonly required to grind a batch of three to four hundred pounds.

Edge runner mills of larger capacity have been installed in several plants. These likewise are constructed of wood. The pans vary in size up to 10 feet in diameter and 36 inches in depth, the wooden bottom being constructed of end-grain blocks. Four wooden rollers approximately 30 inches in diameter, with 24-inch faces, revolve around a central shaft. These rollers are so arranged that they can be raised and lowered, depending upon the height of the charge in the mill. Washed mica scrap is placed in the mill, water is added, and the rollers are lowered so that they are in contact with the charge. The rollers revolve at comparatively low speed and churn the mass until grinding is completed.

The wet ground mica is sluiced from the grinding mill to a settling tank, the supernatent water from one tank often being led to another in which the finest mica is recovered. From the settling tanks the wet mica is shoveled out and dried on steam tables, after which it is screened, generally on 160-mesh. Oversize material is returned for further grinding, and the undersize is sacked for shipment.

Dry Grinding

A number of devices have been employed to grind dry mica, and many processes have been attempted that involve heating to promote its disintegration. Buhr mills and emery mills have been used with varying degrees of success. Hammer mills are used in some plants, the ground mica discharged through the mill screens being elevated to multiple-deck vibrating screens that produce the size required. This process has been described in detail.6/ In recent installations Marcy rod mills have been employed successfully.

6/ Antisell, T., Mica Mining and Milling Methods: Eng. and Min. Jour., vol. 122, No. 23,1926, pp. 894-896.

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WORLD PRODUCTION

The annual world output of sheet mica has grown in three decades from 1,250 to over 11,000 short tons. The world production of scrap and ground mica has also increased greatly, but no figures on the production of scrap and ground mica are available. India has long been the leading producer of sheet mica; however, other British possessions, notably Canada, which produces phlogopite, and South Africa and Rhodesia, which have recently greatly expanded their output of muscovite, also contribute substantially to filling the rapidly increasing demand for mica. Madagascar has become a large source of phlogopite sheet and splittings. Argentina, Brazil, Guatemala, Japan, and Russia produce minor quantities of mica. During the last decade for which figures are available (1919 to 1928 inclusive) the United States produced approximately 11 per cent of the world's output of sheet mica.

Available figures of the world's production of sheet mica for 1900 to 1928 and the percentages represented by the production of the United States are shown in the following table:

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World production of sheet mica, 1900 - 1928, in short tons

Year	United States	India 1/	Madagascar 2/	Canada 3/	Other countries 4/	Total 5/	Percentage of total in the United States
1900	228	1,026	- -	(6)	1	1,255	18
1901	180	1,274	- -	(6)	1	1,455	12
1902	187	1,143	- -	(6)	85	1,415	13
1903	310	1,206	- -	(6)	39	1,555	20
1904	334	1,022	- -	(6)	13	1,369	24
1905	462	1,447	- -	(6)	15	1,924	24
1906	712	3,039	- -	287	49	4,087	17
1907	530	2,187	- -	387	54	3,158	17
1908	486	7/2,677	1	218	124	3,506	14
1909	905	1,828	- -	185	122	3,040	30
1910	1,238	2,218	- -	379	172	4,007	31
1911	944	2,595	(8)	295	207	4,041	23
1912	423	3,328	- -	290	217	4,253	10
1913	850	3,499	6	552	184	5,091	17
1914	278	2,268	3	298	130	2,977	9
1915	277	1,702	1	209	118	2,307	12
1916	433	3,063	3	604	107	4,210	10
1917	638	3,503	(8)	583	265	4,989	13
1918	822	3,357	4	374	485	5,042	16
1919	773	3,309	21	647	584	5,334	14
1920	842	4,285	55	770	483	6,435	13
1921	371	7/1,819	155	198	325	2,868	13
1922	539	2,416	101	197	285	3,538	15
1923	1,032	4,665	182	455	808	7,142	14
1924	730	3,925	315	681	1,927	7,578	10
1925	897	5,583	294	480	3,629	10,883	8
1926	1,086	5,037	326	306	2,008	8,763	12
1927	756	4,339	600	390	3,771	9,856	8
1928	841	5,347	700	58	4,382	11,228	8

1/ Figures represent exports except as otherwise stated.
2/ Exports.
3/ Figures for 1914 - 18 estimated by U. S. Geological Survey on the basis of one-half of total reported production of mica in Canada. Figures for 1919 and 1920 compiled from official reports of the Departments of Mines of Ontario and Quebec. Figures for other years as reported by Dominion Bureau of Statistics.
4/ Some scrap mica included, as data are not reported separately for some countries. The figures, also, are not complete, as production data are not available for some countries, especially in the period, 1913-1918, inclusive.
5/ Total covers only countries for which statistics reported.
6/ Figures not available.
7/ Production as reported by Geological Survey of India.
8/ Less than 1 ton.

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DOMESTIC PRODUCTION

The mining of mica in the United States is a small industry. The aggregate value of the mine product fluctuates greatly from year to year but rarely exceeds $500,000 in any one year. When properly graded and prepared for market the value of domestic output is of course considerably larger than the price paid to the miners, but even then the total value is not very great. Production figures for rough-trimmed and cut mica show a general upward trend, beginning in 1896 and rising to a maximum of 2,476,190 pounds in 1910. During the World War there was a decline, but since 1918 the output of uncut sheet mica has varied from 741,845 pounds in 1921 to 2,172,159 pounds in 1926, the average being only a trifle higher than before the war. In 1928 only 1,620,000 pounds valued at $259,200 was produced.

The output of scrap mica has varied greatly from year to year. Since 1921, however, the quantity annually produced has definitely increased, averaging 7,156 short tons valued at $127,451 for the five year period, 1922 to 1927 inclusive, as compared with 4,043 short tons valued at $55,396 for the pre-war years, 1909 to 1913.

New Hampshire and North Carolina are the chief producing states. Normally, fully one-half of the American output of sheet mica has come from New Hampshire and more than one-third from North Carolina. Both of these states, especially North Carolina, produce yearly large quantities of scrap mica, although substantial quantities of this quality of mica are also produced in other states, notably Colorado, Connecticut, New Mexico, and South Dakota.

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Mica produced in the United States, 1880-1927

Year	Rough trimmed and cut mica		Scrap mica		Total quantity (short tons)	Total value
	Quantity (pounds)	Value	Quantity (short tons)	Value		
1880	81,669	$127,825			41	$127,825
1881	100,000	250,000			50	250,000
1882	100,000	250,000			50	250,000
1883	114,000	285,000			57	285,000
1884	147,410	368,525			74	368,525
1885	92,000	161,000			46	161,000
1886	40,000	70,000	1,000	$10,000	1,020	80,000
1887	70,000	142,250	2,000	15,000	2,035	157,250
1888	48,000	70,000			24	70,000
1889	49,500	50,000	196	2,450	221	52,450
1890	60,000	75,000	496	6,200	526	81,200
1891	75,000	100,000			38	100,000
1892	75,000	100,000			38	100,000
1893	51,111	80,629	156	8,300	182	88,929
1894	35,943	43,793	191	8,595	209	52,388
1895	44,325	50,381	148	5,450	170	55,831
1896	49,156	65,441	222	1,750	247	67,191
1897	82,676	80,774	740	14,452	781	95,226
1898	129,520	103,534	3,999	27,564	4,064	131,098
1899	108,570	70,587	1,505	30,878	1,559	121,465
1900	456,283	92,758	5,497	55,202	5,725	147,960
1901	360,060	98,859	2,171	19,719	2,351	118,578
1902	373,266	83,843	1,400	35,006	1,587	118,849
1903	619,600	118,088	1,659	25,040	1,969	143,128
1904	668,358	109,462	1,096	10,854	1,430	120,316
1905	924,875	160,732	1,126	17,856	1,588	178,588
1906	1,423,100	252,248	1,489	22,742	2,201	274,990
1907	1,060,182	349,311	3,025	42,800	3,555	392,111
1908	972,964	234,021	2,417	33,904	2,853	267,925
1909	1,809,582	234,482	4,090	46,047	4,995	280,529
1910	2,476,190	283,832	4,065	53,265	5,303	337,097
1911	1,887,201	310,254	3,512	45,550	4,456	355,804
1912	845,483	282,823	3,226	49,073	3,649	331,896
1913	1,700,677	353,517	5,322	82,543	6,172	436,060
1914	556,933	278,540	3,730	51,416	4,008	329,956
1915	553,821	378,259	3,959	50,510	4,236	428,769
1916	865,863	524,485	4,433	69,906	4,866	594,391
1917	1,276,535	753,874	3,429	52,908	4,067	806,782
1918	1,644,200	731,810	2,292	33,130	3,114	764,940
1919	1,545,709	483,567	3,258	58,084	4,031	541,651
1920	1,683,480 1/	546,972 1/	5,723	167,017	6,565	713,989
1921	741,845 1/	118,513 1/	2,577	56,849	2,948	175,362
1922	1,077,968	194,301	6,641	114,045	7,180	308,346
1923	2,063,179	311,180	8,054	129,695	9,086	440,875
1924	1,460,897	212,035	4,709	87,242	5,439	299,277
1925	1,793,865	321,962	9,695	173,537	10,592	495,499
1926	2,172,159	400,184	7,043	136,643	8,129	536,827
1927	1,512,492	212,482	6,280	110,139	7,036	322,621

1/ The figures for sheet mica in 1920 and 1921 represent uncut sheet mica exclusively. In previous years the totals have included some cut sheet mica.

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IMPORTS

In 1928 the United States imported for consumption, exclusive of scrap mica, a total of 4,104,885 pounds of mica having an aggregate value (foreign-market value) of $1,426,495. As may be noted in the following table, the bulk of this importation consisted of mica splittings, which normally constitute about three-fourths of the quantity and about two-thirds of the value of the recorded imports.

Mica imported for consumption to the United States, 1927-28

Kinds	1927		1928	
	Quantity (pounds)	Value	Quantity (pounds)	Value
Manufactured				
Cut	64,075	75,469	49,555	93,964
Splittings	2,588,253	1,123,808	3,496,353	1,025,790
Ground	-	-	150	53
Built-up	8,097	9,211	4,896	4,539
Washers	1,732	536	3,296	1,291
Manufactures	21,183	21,983	9,000	6,664
Manufactured total	2,683,340	1,231,007	3,563,250	1,132,301
Unmanufactured total	776,307	399,302	541,635	294,194
Grand total	3,459,647	1,630,309	4,104,885	1,426,495

The foregoing table does not include scrap mica, which though imported in substantial quantities has hitherto been reported under the general classification, "Waste not specially provided for." One company alone, however, is said to have purchased about 3,000 tons in 1928, and the total imports of scrap mica for that year probably amounted to at least 5,000 tons, most of which came from India and Africa. India is by far the principal source of splittings and most of the other forms of mica imported into the United States. In recent years about two-thirds of the total imports of mica have come direct from India, and further quantities of India mica, including manufactures, have been imported by way of Great Britain and other European countries. Canada, however, is an important source of unmanufactured mica, and in the case of ground mica, valued at not above 15 cents per pound, is the principal source of supply. The imports from Canada probably consist almost wholly of amber mica, and mica of this quality is imported in small, though increasing quantities, from Madagascar. The imports of splittings from Madagascar, combined with those from France--which doubtless likewise originated in Madagascar--exceeded those from Canada in 1928. The small imports of built-up mica are mainly from Germany, which also ranks as the most important European source of other forms of manufactured mica (except washers), of which British India again is the leading country of origin. A number of countries, however, contribute to our supply of mica, particularly the unmanufactured grades. Of these countries South Africa, Argentina, Brazil, Chile, Czechoslovakia, Guatemala, and Mozambique have all appeared in the statistics in recent years, in addition to France, Great Britain, Germany, and other European countries, imports from which are probably transshipments.

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TARIFF

Under the tariff act of 1922, scrap mica was dutiable at 10 per cent ad valorem under paragraph 1457 as "Waste not specially provided for." In the draft of tariff bill H. R. 2667, as reported by the finance committee to the Senate on September 4, 1929 (paragraph 208), the duties of both scrap and ground mica were reduced to 5 per cent, a reduction of 5 per cent on scrap and of 15 per cent on ground mica. Increases were recommended on cut or trimmed mica from 30 per cent to 35 per cent; and on unmanufactured mica valued at over 15 cents a pound, a compound rate of 2 cents per pound and 25 per cent ad valorem was proposed in lieu of the existing rate of 25 per cent.

EXPORTS

Exports are chiefly of the manufactured or semimanufactured forms and go principally to Canada, with England and France the next largest consumers. Statistics do not show the nature of these mica manufactures, but the Tariff Commission 7/ ventures the opinion that since the value has ranged in recent years from 7 to 11 cents a pound they are prepared from ground mica and are probably lubricants.

Mica exported from the United States, 1910-1928

Year	Pounds 1/	Value	Value per pound 1/
1910	.....	$20,543.	.....
1911	.....	35,916	.....
1912	.....	40,812	.....
1913	.....	62,184	.....
1914	.....	50,896	.....
1915	.....	39,033	.....
1916	.....	78,671	.....
1917	.....	74,485	.....
1918	.....	74,529	.....
1919	.....	109,348	.....
1920	.....	316,169	.....
1921	.....	153,990	.....
1922	1,134,397	129,286	$0.114
1923	1,804,342	182,162	0.101
1924	1,519,636	169,741	.112
1925	2,422,197	198,596	.082
1926	2,326,131	230,511	.099
1927	2,867,798	207,263	.072
1928	3,661,587	229,391	.062

1/ Not available before 1922.

7/ Summary of Tariff Information, 1929. Schedule 2, Earths, Earthenware, and Glassware, p. 466.

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Size	Square inches
No. A1	36 to 47
No. 1	24 to 33
No. 2	14 to 23
No. 3	10 to 13
No. 4	6 to 9
No. 5	3 to 5
No. 6	1 to 3

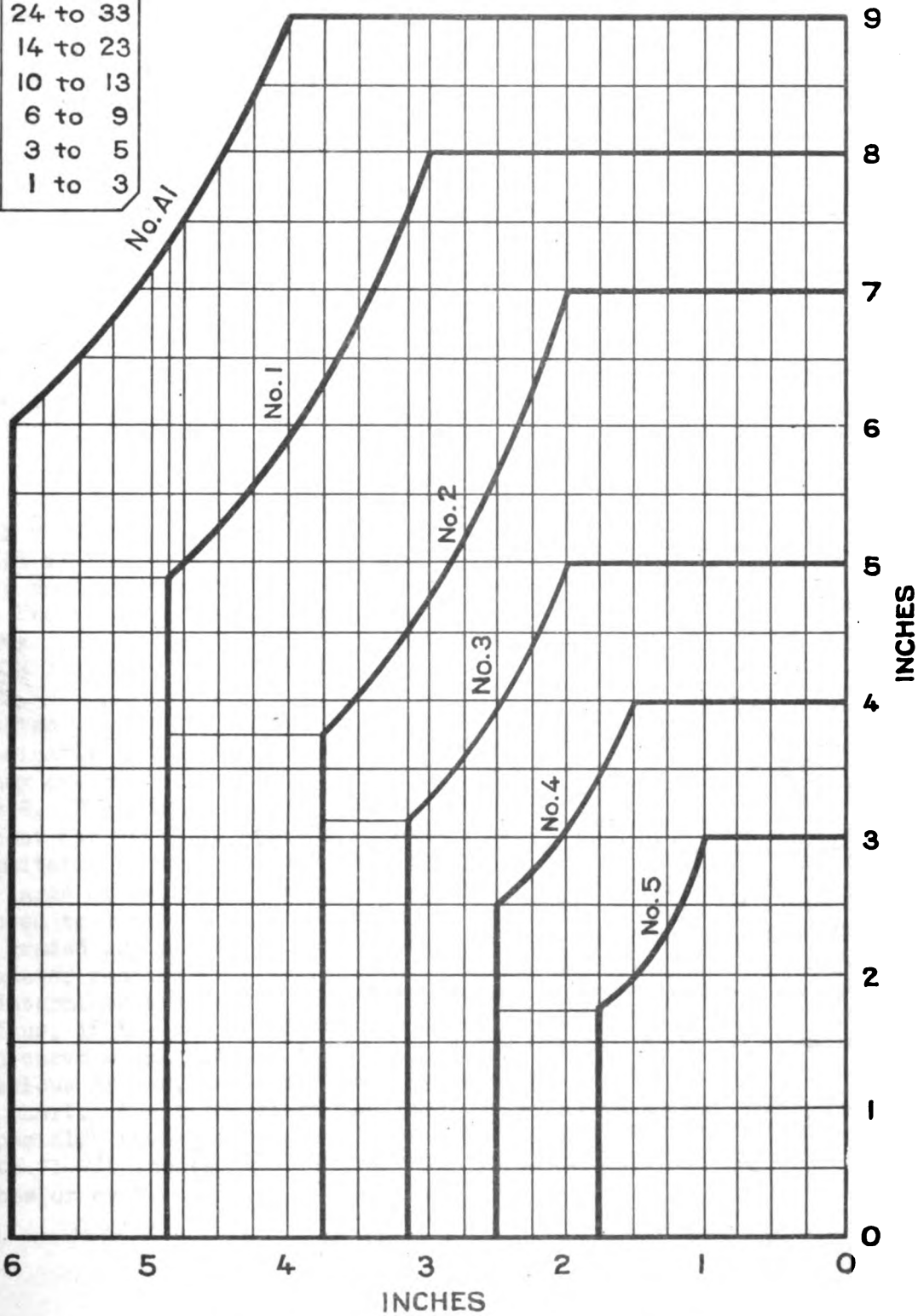

Chart for India grading of mica according to size

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GRADES AND SPECIFICATIONS

Classification

As regards quality, American mica is classified into three principal grades: (1) clear, (2) slightly stained or spotted, and (3) heavily stained or spotted. Although this basis of classification is not objectionable, the absence of definite limits for each grade causes much confusion and often results in improper grading.

As regards classification by size, the United States, Canadian and Indian systems are all different. In general the United States and Canada micas are classed on the basis of rectangular dimensions of pieces that may be cut from the sheets, while the India classes are on the basis of area in square inches of the rectangles that may be obtained.

The United States classification is as follows: The lowest grade of sheet mica is designated as "punch." The uncut sheet must be large enough to yield a circle $1\frac{1}{2}$ inches in diameter if stained and $1\frac{1}{4}$ inches if clear. The next size, "circle", should provide a disk nearly 2 inches in diameter. The smallest rectangle is $1\frac{1}{2}$ x 2 inches and the sizes following are 2 x 2; 2 x 3; 3 x 3; 3 x 4; 3 x 5; 4 x 6; 6 x 6; 6 x 8; 8 x 10; and larger. When properly trimmed the uncut mica sheet is approximately one and one-half times as large as the maximum standard rectangle that may be cut from it. Each class includes the size designated and all larger sizes until the next class is reached; thus a sheet that would cut to a rectangle $3\frac{1}{2}$ x $5\frac{1}{2}$ inches or $3\frac{1}{2}$ x 6 inches would be classed as 3 x 5.

Canadian phlogopite is also classed on the basis of dimensions of rectangles obtainable, but the sizes differ somewhat from the United States standards. They are as follows: 1 x 1; 1 x 2; 1 x 3; 2 x 3; 2 x 4; 3 x 5; 4 x 6; and 6 x 8. The Indian classification is based upon the area of usable mica in the sheet for which 10 arbitrary classes have been provided. Of course some limitation must be placed on dimensions, for long narrow strips, though having large areas, would be suitable for few purposes. The accompanying chart is used to classify mica according to the India grades. The blocks of mica to be graded are placed at the lower right corner of the chart, with the longer diameter running vertically. The position of the upper left corner of the block determines its grade. The curves indicate the minimum size of each grade. Thus, if the corner of the block is located left of curve 3 but does not reach curve 2 the mica is in No. 3 grade. The approximate range in area of the various grades, in square inches, is shown in the upper left corner of the chart. The three sizes too large to be shown on the sheet are designated "special," having a range of area 48 to 59-7/8 inches; "extra special," 60 to 71-7/8 inches; and "extra extra special," having an area of 72 square inches or over.

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Specifications

Requirements of mica for electrical purposes relate to dielectric strength, heat resistance, and flexibility. All good electrical mica is sufficiently resistant to heat for ordinary electrical equipment, and this property is therefore rarely specified. Specifications for dielectric strength vary for different uses and with different consumers for similar uses. Mica has such a high dielectric strength that failures occur most commonly in defective spots. Therefore, in selecting material where high dielectric strength is required it is very important that the mica be carefully examined and all defective sheets rejected.

Flexibility is an important property in mica that must be wound into tubes of small diameter. It is commonly specified that mica for wrapping spark plug spindles must be so flexible that a sheet one-thousandth of an inch thick may be bent into a cylinder one-fourth of an inch in diameter without cracking.

For stove use or for similar purposes where transparency is required mica is specified as "clear" and "spotted." In North Carolina stove No. 1 must be free from cracks and stains but may contain "air bubbles," but stove No. 2 may be spotted and stained to a limited extent. There is great need of more rigid and clearly defined specifications for this property, as some mica sold at present as "clear" is decidedly spotted.

Many specifications for sheet mica call for India mica. This is due partly to the erroneous impression that India mica is inherently of superior quality and partly to prejudice against domestic mica, due to its improper grading and trimming. A rigid specification that rules out all but India mica certainly discourages development of the domestic industry, and domestic producers should endeavor to have specifications modified to read "India mica or its equivalent." This would give the domestic producer a better opportunity to market a product of equal quality with the imported mica and would encourage better grading and standardization of domestic mica.

PRICES

Several dealers in mica issue what they term a "Standard Price List," but the actual sales are transacted on the basis of discounts, sometimes as high as 90 per cent off this list. Owing to the multiplicity of sizes and differences real and fancied in quality, it is impossible to represent the market situation accurately by means of any single schedule of prices. Even the product of a single mine may be sold at widely different prices, and the only rule is that prices under every contract and often under individual sales are arrived at through a process of bargaining between buyer and seller. In the United States prices of scrap mica have averaged recently from $14 to $25 a short ton at the mines. Often mines sell their entire output as ungraded or run-of-mine block mica at a flat price per ton. Others grade their product more or less carefully. As may be seen from the following table, the prices received vary between wide limits.

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Price and value of domestic mica marketed in the United States from 1900 to 1927

Year	Total value	Average price per short ton of all mica mined	Average price per pound of sheet and punch mica
1900	$147,960	$26	$0.20
1901	118,578	50	.27
1902	118,849	75	.22
1903	143,128	73	.19
1904	120,316	84	.16
1905	178,588	112	.17
1906	274,990	125	.18
1907	392,111	110	.33
1908	267,925	92	.24
1909	280,529	56	.13
1910	337,097	64	.10
1911	355,804	80	.17
1912	331,896	91	.33
1913	436,060	71	.21
1914	329,956	82	.50
1915	428,769	101	.68
1916	594,391	122	.61
1917	806,782	198	.59
1918	764,940	246	.45
1919	541,651	134	.31
1920	713,989	109	.32
1921	175,362	59	.16
1922	308,346	43	.18
1923	440,875	49	.15
1924	299,277	55	.15
1925	495,499	47	.18
1926	536,827	66	.18
1927	322,621	46	.14

Range of prices per pound for rough-trimmed uncut sheet mica in 1927[1/]

Size	Clear	Stained	Size	Clear	Stained
Punch	$0.05-$0.15	$0.04-$0.13	3 by 4 inches	$1.20-$2.20	$0.85-$1.50
1½ by 2 inches	.25- .35	.20- .25	3 by 5 inches	1.75- 2.64	1.10- 1.75
2 by 2 inches	.40- .85	.15- .35	4 by 6 inches	2.00- 3.50	1.50- 2.00
2 by 3 inches	.67- 1.30	.30- .60	6 by 8 inches	3.75- 5.00	1.75- 4.25
3 by 3 inches	1.00- 2.15	.60- 1.30	8 by 10 inches	7.00- 8.00	2.50- 3.00

1/ As reported to the Bureau of Mines by producers and others engaged in the industry.

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On the basis of the total quantity and sales value of mica produced each year as reported to the Bureau of Mines it is possible to figure out the average prices obtained by producers. It will be noted from the accompanying table that the average price received per ton has ranged from a minimum of $26 in 1900 to a maximum of $246 in 1918, and that the average price obtained per pound of mica marketed as sheet, likewise, has varied greatly. Variations in these figures over a period of years indicate little, if anything, with regard to the long-time trends of prices, because data are lacking to show variations in the respective proportions of expensive large-sheet mica and of cheaper sizes.

OTHER VARIETIES OF MICA

A great number of different varieties of mica are known to the mineralogist, but most of them are of rare occurrence and of no commercial importance. A few of the micas other than muscovite and phlogopite, however, are of some industrial significance and merit attention. The most prominent examples of these unusual micas that are of some practical value are biotite, lepidolite, roscoelite, and sericite.

Biotite

Biotite, the black iron-bearing mica, has found little industrial application. This mica is a common constituent of many of the dark granites and is also found in schists associated with garnet, amphibole and other minerals. In these rocks it occurs in small scales that can not be separated readily. It occurs frequently in pegmatites, and even when it occurs in large sheets its presence is very objectionable where the pegmatite is being worked for feldspar. This mica does not possess the perfect cleavage of muscovite or phlogopite and can not be split into thin sheets easily.

The objections to a wider use of biotite are its unattractive color and high iron content. The following analyses are more or less typical.

Analyses of biotite[1/]

	Auburn, Maine	Butte, Mont.		Auburn, Maine	Butte, Mont.
SiO_2	34.67	35.79	LiO_2	- - -	Trace
TiO_2	- - -	3.51	Na_2O	1.67	.15
Al_2O_3	30.09	13.70	K_2O	7.55	9.09
Fe_2O_3	2.42	5.22	H_2O-	4.64	1.21
FeO	16.14	13.72	H_2O	- - -	3.64
MnO	.85	.19	P_2O_5	- - -	.10
CaO	- - -	.05	F	.28	.76
BaO	- - -	.13	Ce	- - -	.20
MgO	1.98	12.13	Total	100.29	99.59

1/ Clarke, F. W., Analyses of Rocks and Minerals: U. S. Geol. Survey, Bull. 591, 1915, p. 333.

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The composition of different biotites displays great variation, as may be expected, and an endless substitution of the different radicals makes possible the formation of a long series of dark micas which are all loosely classified as biotites. Biotite commonly exhibits a dull luster although specimens are found at times which after cleavage to a new surface display a bright and resplendent surface.

Some attempts have been made to use biotite for roofing mica, but they have not been successful due to the limited supply of the material and its dull color. Since its cleavage is not developed highly enough to permit the separation of aggregates into very thin sheets when ground, ground biotite does not have as great a surface or covering power as other micas, when used to coat such materials as rolled roofing. If any demand for biotite should arise which could be satisfied by material in small scales the most likely source would be the mines that are operated for abrasive garnet. Such mines are located in New York and North Carolina, and in some of the deposits the garnet is associated with biotite in a schist. During concentration of the garnet the mica is separated and thrown away. Recovery of the mica would be possible if there was a market that would make the operation profitable.

Schists, composed essentially of biotite with such accessory minerals as quartz, feldspar, and garnet, have been used for grinding to produce a filler similar to that obtained by grinding scrap mica. The grinding procedure is also similar.

The biotite schist is mined in small, irregular excavations from which the rock is recovered with a minimum of expense. After transportation to the grinding mill it is passed through a jaw crusher and then rollers which reduce it to minus 10-mesh. From the rollers it is fed to wet chaser mills and ground in batches, following the same procedure employed for the production of wet-ground mica. A charge of 1½ tons requires an average of six hours grinding. When a batch is finished the contents of the mill are sluiced to a settling tank, where the sand and grit are permitted to settle out. The overflow is conveyed to another settling tank where the mica settles in a sludge which is later filter pressed to remove as much water as possible. The filter cake is dried on steam coils, broken up in a hammer mill, and passed over a scalping screen to remove trash. The mica is then screened through 160-mesh gauze on bolting trommels and the oversize is returned to the mill. The minus 160-mesh material is marketed as a filler.

Lepidolite

Lepidolite is frequently known as the lithium mica, due to its uncommonly high content of this element. It is rarely found in crystals large enough to permit the separation of sheets of appreciable dimensions. It occurs characteristically in massive aggregates composed of small intergrown scales less than one-eighth of an inch in their greatest dimension. In some instances these scales are so small that they can not be discerned without magnification, and the mineral appears to be a homogeneous mass. Lilac, lavendar, and shades of pink are its typical colors, although it is found in various shades of brown and gray and even is white in some instances. It is placed at 2 in the scale

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of fusibility. No occurrences of lepidolite from which sheet mica could be obtained have been reported in the United States. In Western Australia pegmatites bearing lithium minerals are of common occurrence. In the Coolgardie-Londonderry area large crystals of lepidolite have been recovered. Clear sheets 1 foot across were easily obtained. This mica split readily and attracted favorable attention, but the remoteness of the deposits has retarded their development and the industrial use of the mica has been restricted due to its low fusibility.

Analyses of Lepidolite1/

	Paris, Maine	Auburn, Maine		Paris, Maine	Auburn, Maine
SiO_2	50.92	49.62	LiO_2	4.20	4.34
Al_2O_3	24.99	27.30	Na_2O	2.11	2.17
Fe_2O_3	.30	.31	K_2O	11.38	8.03
FeO	.23	.07	Rb_2O	Trace	2.44
MnO	Trace	.55	Cs_2O	Trace	.72
CaO	Trace	- - -	H_2O	1.96	1.52
MgO	Trace	- - -	F	6.29	5.45
			Total	102.38	102.52

1/ Clarke, F. W., Analyses of Rocks and Minerals: U. S. Geol. Survey, Bull. 591, 1915, p. 331.

Lepidolite resembles muscovite in occurrence, in that it is found in pegmatite formations. It has been reported in Maine and Connecticut, where it is found in the quarrying of feldspar. These occurrences apparently have no commercial significance, as the tonnage available is very small. It is found most abundantly in the Black Hills section of South Dakota, in San Diego County, California, and in Rio Arriba County, New Mexico.8/ Prospecting and mining operations have disclosed appreciable tonnages in these areas.

Lepidolite has been used to a limited extent as a source of lithium. This element is found in the minerals amblygonite and spodumene in greater percentage and is more easily recovered than from lepidolite. The resources of amblygonite and spodumene in South Dakota appear ample to satisfy the limited market for lithia, and it appears improbable that lepidolite will be in any immediate demand for this purpose. Zinnwaldite, likewise belonging to the mica group, has been mined in Europe for its lithia content, but no commercial deposits of this mineral are known in the United States.

The use of lepidolite as a raw material in the manufacture of ceramic products has attracted increasing attention during the past few years. The manufacture of opaque glass consumes the largest tonnage of the mineral at present. Lepidolite, like feldspar, introduces alumina and alkali into the glass batch and the fluorine and lithia content of the mineral are both valuable fluxing agents. Lepidolite is serviceable especially in the production of opal and white glass.

8/ Roos, A., Mining Lepidolite in New Mexico: Eng.Min.Jour.-Press, vol.121, No. 26, 1926, pp. 1037-1042.

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Merely as an opacifier, fluorspar is apparently as effective as lepidolite and being much cheaper is generally used in opal glasses and enamels but the presence of lithia is believed to be of value in the manufacture of glasses used for heat-resisting purposes. Ladoo[9] states:-

"Some of the qualities which lepidolite is attributed to impart directly or indirectly to glass are as follows: a lowering of the coefficient of expansion, thus decreasing the liability to breakage on sudden heating and cooling; the tendency to reduce devitrification or the production of "scum" in the melt; the production of a harder surface on the finished glass, which will retain its luster in moist air; lepidolite glass is less brittle and withstands shocks and vibrations; lepidolite increases the index of refraction and hence the brilliancy of the glass; it obviates the corrosion of glass tanks, when making opal glass, attendant upon the use of cryolite instead of lepidolite as an opacifying agent. A typical opal batch given by B. F. Drakenfeld & Co. is as follows:

	Opal glass batch
Sand	2,000 pounds
Soda	750 pounds
Lime, (burned)	40 pounds
Feldspar	240 pounds
Fluorspar	580 pounds
Lepidolite	1,420 pounds
Arsenic	10 pounds
Color	10 ounces

"Lithium minerals are also used to some extent in enamel and glazes."

For utilization in glass it is essential that the iron content should not exceed 0.05 per cent of ferric oxide. The material should be ground to pass a 40-mesh screen or to the requirements of the purchaser. More lepidolite would undoubtedly be used in the glass industry if the deposits were nearer the principal glass-producing districts in Pennsylvania and West Virginia; the relatively high cost of bringing the material from California or New Mexico eastward tends to restrict its use.

Continued investigation of the ceramic possibilities of lepidolite indicates that a market of potential importance exists in this field, provided the material can be delivered cheaply enough to compete on a price and technical basis with materials now in use.

Twells[10] has investigated the effect of lepidolite in high tension electrical porcelain bodies. An abstract of this article states:

"Lepidolite is a lithium mica which has had considerable commercial application in glass and enamels. Its use in porcelain has not been tried to

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9/ Ladoo, R. B., Nonmetallic Minerals; Occurrence, Preparation, Utilization, New York, 1925, p. 322.

10/ Twells, R., The Effect of Lepidolite in a High Tension Electrical Porcelain Body: Jour. Am. Ceram. Soc., vol. 11, No. 8, 1928, pp. 644-648.

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any great extent. This work covers the replacement by lepidolite of the feldspar in a high-tension electrical porcelain. The results show that changing the RO of the standard body by molecularly replacing K_2O by Li_2O raises the vitrification temperature of the body, but that replacing feldspar directly pound for pound by lepidolite greatly lowers the vitrification temperature of the body. Lepidolite gives porcelains a fine appearance and extreme whiteness. The most important property noted is an improvement of the bodies containing lepidolite in resistance to thermal shocks. Owing to its higher cost it is unlikely that lepidolite will be used in porcelains except in small proportions with feldspar to produce bodies having special properties. As hitherto the most important applications of lepidolite will doubtless be in glasses and enamels where full benefit can be secured from its fluorine content and low fusion temperature."

The possible use of lepidolite in terra cotta glazes has also been investigated. Davis [11] substituted lepidolite for feldspar in a standard glaze formula in increasing amounts and determined the results. His conclusions were not positive with regard to crazing. The results exhibited on test pieces displayed a beautiful glaze surface; and considered as a glaze material only, its cost was not considered prohibitive. It was believed that further experiments would place this little-used mineral on the regular list of glaze ingredients.

Roscoelite

Roscoelite is often known as vanadium mica, due to its content of this element. It is found only in small scales; large sheets are unknown. Analyses[12] are as follows:

Analyses of Roscoelite

(Soluble portion of vanadiferous sandstone)

	Eldorado County, Calif.	Placerville, Colo.		Eldorado County, Calif.	Placerville, Colo.
SiO_2	45.17	46.06	BaO	- - -	1.35
TiO_2	.78	- - -	MgO	1.64	.92
Al_2O_3	11.54	22.55	LiO_2	Trace	- - -
V_2O_3	24.01	12.84	Na_2O	Trace	.22
Fe_2O_3	- - -	.73	K_2O	10.37	8.84
FeO	1.60	- - -	H_2O	4.69	6.05
CaO	- - -	.44	Total	99.80	100.00

Vanadiferous sandstones occurring near Bear Creek, Fall Creek and Placerville, Colo., in which the vanadium is present in roscoelite, and other

11/ Davis, H. E., Lepidolite in Cone 6 Terra Cotta Glazes. Jour. Am. Ceram. Soc., vol. 12, No. 9, 1929, pp. 570-571.

12/ Clarke, F. W., Analyses of Rocks and Minerals: U. S. Geol. Survey, Bull. 591, 1915, p. 334.

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related minerals contributed approximately 18 per cent of the world's supply of vanadium up to the end of 1923.13/ The location of the ore bodies and their geology and origin have been discussed by Hess.14/ Roscoelite appears in this ore as a cement which bonds the grains of sand, the scales of roscoelite being almost submicroscopic in size. Roscoelite-bearing sandstones on East Rifle Creek, Colo., were the principal source of vanadium mined in this country in 1923.

Sericite

Sericite may be considered a muscovite of secondary origin. It resembles muscovite in composition but differs from it greatly in form as it commonly occurs in aggregates composed of very small scales. In this condition it is a common constituent of many sedimentary and metamorphic rocks. It is also found in segregations of considerable purity from which commercial material may be recovered and in this form it tends to exhibit a fibrous structure and greasy feel which have resulted in its being frequently confused with talc. Its origin is believed to be due to the action of high temperatures, mechanical stress, and the chemical activity of water on feldspathic rocks.15/

Sericite is prepared for market by grinding in hammer mills similar to scrap mica. Grinding is somewhat less difficult, as the disintegration of the aggregates of small scales is easier than tearing the larger sheets of muscovite. The principal use of sericite is in the rubber industry. It is used for dusting molds in which tires are formed and for this purpose it is claimed to be very serviceable in that it permits sharp impressions of the lettering on the exterior of the tire. It is also used for dusting black rubber. Due to the smaller size of the individual scales it is absorbed more readily by the rubber than ordinary mica, and where a black surface is desired this becomes an asset. Common ground mica with a larger area in each scale is not absorbed so easily and may produce a silvery sheen, which is objectionable on black goods.

Sericite is widely distributed, but commercial production has been small and limited principally to the sericitic schists of Georgia. The Georgia schists and shales represent an important potential source of potash as they contain 8 per cent of K_2O in the form of sericite. During the World War, when imports of German potash were interrupted, considerable interest was displayed in the possibility of obtaining potash from these rocks. Despite the difficulties of breaking down a complex silicate, at least one apparently suitable process was devised for making the potash content available, but the method was never established on a commercial scale.

13/ Report of the Subcommittee on Vanadium Min. and Met. Soc. of Am., Bull. 175, 1925, p. 28.

14/ Hess, F. L., Vanadium Deposits near Placerville, Colo., and in the Sierre De Los Caballos, N. M., U. S. Geol. Survey, Bull. 530, 1913, pp. 142-160.
Hess, F. L., Marketing of Vanadium Ores and Metal: Eng. and Min. Jour.-Press, vol. 118, No. 18, 1924, pp. 694-698.

15/ Clarke, F. W., The Data of Geochemistry; Sericitization: U. S. Geol. Survey, Bull. 770, 1924, pp. 604-605.

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Sericite associated with dumortierite occurs in a schistose formation in the Rochester mining district of Nevada.[16] The Commercial utilization of this material likewise has attracted considerable attention. The rock contains approximately 75 per cent of dumortierite and 14 per cent of sericite, the remainder being quartz and other minerals.

When heated the dumortierite breaks down and begins to dissociate near 1,250° C., forming a mullite similar to that obtained from andalusite. This sericite-dumortierite mixture has been utilized in the manufacture of spark-plug porcelains with very promising results. Its use as a refractory has also been suggested. The behavior of the sericite under these conditions and the value of its presence have not yet been determined accurately.

MATERIALS ALLIED TO MICA

Vermiculite

The term "vermiculite" is applied to a group of micaceous minerals that generally are alteration products of mica. The original cleavage is partly retained; other physical properties and the chemical composition show varying degrees of alteration. Until a few years ago the known deposits were so small that vermiculite was considered a mineralogical curiosity. The most pronounced characteristic of vermiculites is great expansion on heating. This expansion or exfoliation takes place in only one direction, at right angles to the cleavage, and during expansion the volume increases up to 16 times the original. At the same time the color changes from black or dark brown to a silvery or golden hue, according to the degree of heat and the exposure to the air. This change of color is believed to be due to the oxidation of the iron, and it may be controlled to a limited extent by excluding air during heating. In an atmosphere of diminished oxygen content the oxidation is incomplete and the color decreased in intensity.

A variety of vermiculite known as "jefferisite" was first found at the Brinton quarry, West Chester, Pa., and for a time this was the only known occurrence in the country. It was discovered later in Colorado, and some unsuccessful attempts were made to utilize it industrially. The discovery of considerable tonnages of this material in Montana attracted attention to its peculiar properties, and since 1921 a continued effort has been made to find commercial uses for it.

The Montana deposits are located in the Kootenai Valley 9 miles northeast of Libby, a town on the Great Northern Railroad. A typical analysis[16] of this material after heating is as follows.

Loss on ignition	0.7
Silica .....(SiO_2)	42.8
Iron and alumina oxides	26.2
Lime .....(CaO)	1.9
Magnesia .....(MgO)	24.6
Soda and Potassium (Na_2O & K_2O)	3.8
	100.0

16/ Alley, E. N., Zonolite; Utilizing a Useless Mineral: Eng. and Min. Jour.-Press, vol. 120, No. 21, 1925, pp. 819-820.

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The high-magnesia content of jefferisite suggests its derivation from phlogopite, whose optical characteristics are similar. The specific gravity of the mineral is given as 2.5. After heating, the expanded mass has been reported to have a gravity as low as 0.087. The average product is heavier than this and varies in weight from 6 to 20 pounds per cubic foot. This material is called "Zonolite" locally and for trade purposes.

The mining and treatment of vermiculite in Montana have been described as follows.17/

"Zonolite is mined at a reasonable expense by the caving system and the costs will be further reduced by the installation of a projected aerial tram. The mineral may then be worked off from the grass roots with drag lines and the tram will reduce haulage costs.

"The plant now in operation turns out a product ranging from furnace run and lump to as fine as that passing a 100-mesh screen. In milling, the Zonolite is fed to a 5 foot in diameter by 50 foot long rotary kiln by a screw conveyor. The kiln is lined with four ledges of end wedge fire brick which were constructed the full length of the kiln to facilitate exposure to the heat during the passage of the Zonolite. The heat is developed to 1500 degrees Fahrenheit by a Ray oil burner, introduced at the lower end of the kiln and drawn through with a stack draft.

"After passing through a hammer mill, the product is conveyed to a Williams crusher and pulverizer mill of the BX special type which is directly connected to a 40 hp. motor running at 3,400 r.p.m. It passes through an air separator and is conveyed to a cyclone at the top of the plant. It passes by gravity to the receiving bins which discharge into Rotex screens where it is sieved to the desired fineness. It is then transported to the storage bins to be sacked for shipment as required."

Many potential uses of this material have been determined. For heat and cold insulation it has been recommended for fireless cookers, incubators, pipe and boiler covering, and also as fireproofing material for filing cabinets and vaults. Its attractive golden color has suggested its use as a decorative material in wall paper. It also has possible uses in wall board, kalsomines, and sound deadeners, in foundry work, and for covering galvanizing tanks where the molten zinc must be protected from the air, and similar purposes.

Mica schist

Mica schist is one of the commonest and most widely distributed metamorphic rocks. It is closely related to gneiss and quartzite but is characterized by its conspicuous mica content, which may be either muscovite or biotite. These metamorphic rocks apparently have been formed from siliceous and argillaceous sediments, which have been subjected to varying amounts of heat and compression, causing recrystallization of the original minerals into new combinations. The clay of the sediments may be changed to mica and the sand to compact, crystalline quartz, together with many accessory minerals. The mica is commonly oriented to produce a parallel structure in the rock along which it splits readily.

17/ Pit and Quarry, Quarrying and Refining Zonolite: vol. 16, No.4, 1928, p.82.

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The amount of mica present in the schist is subject to the greatest variation. The striking appearance of the mica scales, with their high reflection of light, is misleading, and the amount of mica present appears to be greater than it actually is. The size of the mica scales also varies greatly, ranging from microscopic to over 1 inch in diameter. The amount of mica in the rock may be only a few per cent, or in some instances it may be present in massive aggregates of intergrown crystals which constitute the bulk of the rock.

Some mica schists have been milled to produce ground mica, as described under biotite mica. For this purpose the schist should have as high a mica content as possible because the presence of other minerals which are valueless complicates the problem of milling and adds to the cost. No definite procedure has been established for utilizing these schists; each local occurrence has to be treated as a different problem. Processes involving the use of air classification and hydraulic concentration have been employed. Experimental work on a commercial scale demonstrated that the mica in a partly kaolinized schist could be recovered by concentration on wet tables, such as are used commonly in the treatment of lead, zinc, copper, and other metallic ores. The disintegrated schist was passed through a log washer to remove kaolin and then conveyed to a ball mill provided with ribbed liners. Ample water was added and the material was ground until the mica aggregates were broken up into separate flakes. The mill pulp was then passed to tables where a successful separation from quartz, the principal gangue mineral, was made. The difference in gravity is almost negligible (0.2) but the flakelike character of the mica aided concentration, as it helped the mica particles to float. The mica concentrate was treated further in a pulsating classifier, producing a product clean enough for commercial use.

Mica schists have been used extensively in masonry construction. When freshly quarried the rock may be readily worked. Generally it is chiseled to 4-inch blocks, which are used for facing. The reflection of the mica scales in the rock produces a lively effect, which is attractive for house construction. The ease with which some schists may be split makes it possible to produce thin slabs suitable for roofing in the same manner as heavy slates are employed.

Considerable quantities of mica schists are used as a refractory in the iron and steel industry. Quarries to supply this market are operated at Glenside, Pa., about 10 miles north of Philadelphia, where the Edge Hill Silica Rock Co. operates a quarry which has been developed systematically. A face 200 by 400 feet is exposed. Holes are drilled by mechanical drills and shot with dynamite, but the large blocks are broken with black powder, so as to produce a minimum of fines. The schist is broken and trimmed to square blocks which are ready for the market. These blocks are employed principally for lining Bessemer converters and also in ladles, cupolas, soaking pits, and hot metal mixers, and even for patching in hot zones. When the schist blocks are laid it is essential that they be placed with the laminations horizontally, otherwise excessive spalling may occur. When heated the mica appears to fuse and bond the whole mass. This self-bonding feature is a desirable asset. Attempts to saw regular shapes have not been successful due to the hardness of the rock. Crushing the rock to produce ~~emi~~ grit was unprofitable because the excessive wear on the crushing equipment required expensive repairs.

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Clinochlore

Clinochlore is a member of the chlorite group of minerals and strictly speaking is not a mica, although it exhibits many similar physical properties and a related chemical composition. It has a basal cleavage like mica, although not quite so well developed. It is of secondary origin and occurs commonly in schists and serpentine, where its characteristic green color is readily recognized. Massive aggregates of clinochlore which were capable of supplying a commercial tonnage of the mineral, have been found occasionally. In these aggregates the clinochlore occurs as a mass of small intergrown scales similar to some varieties of mica schist. Such material has been prepared for market by grinding. The finished product found a limited use for surfacing rolled roofing and as an inert filler. It is inferior to mica in that its covering power is less. Its unattractive color has also limited its industrial utilization.

Chlorite schist, consisting chiefly of clinochlore, was mined and sold for many years at Canton, Cherokee County, Ga., by the American Mica Co., 7 Hanover St., New York City, but operations were discontinued in 1927. Thompson, Weinman & Co., of Cartersville, Ga., reported production at Canton, the material being ground at Cartersville and sold to manufacturers of rubber goods.

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